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THE ZARET FOUNDATION, INC.
1230 POST ROAD
SCARSDALE, NEW YORK

MILTON M. ZARET, M. D.
DIRECTOR OF RESEARCH

CODE 914 GREENLEAF 2-2882

ANNUAL PROGRESS REPORT

1 JUNE 1966 to 31 MAY 1967

CONTRACT DA-49-193-MD-2592

OPHTHALMIC HAZARDS OF MICROWAVE AND LASER ENVIRONMENTS

Milton M. Zaret, M.D.

Principal Investigator

Supported by

U.S. ARMY MEDICAL RESEARCH AND DEVELOPMENT COMMAND

INTRODUCTION

There is an urgent "need-to-know" requirement concerning the parameter of personnel hazard associated with non-ionizing electromagnetic radiation in the form of microwave and laser environments. This information is required for the establishment of meaningful environmental health standards, for the maximal utilization of operational equipments and for a logical pre-selection of wavelengths in research and development of future systems.

Currently, the lack of appropriate knowledge has placed an unwarranted economic and operational burden on the U.S. Army without ensuring the prevention of injury to its personnel. The purpose of this investigation is to determine the nature and scope of ~~the~~ hazards and to recommend the requisite parameters for health-safety.

For both microwave and laser radiation, ophthalmic pathology is the most sensitive indicator of injury. Threshold changes are produced in the lens with microwave radiation and in the retina with laser radiation. As the threshold lesions are not obvious in routine ophthalmic examination, special techniques were ~~have been~~ under development not only to permit discovery of the earliest occurrence of the injury but also to document the findings.

METHODOLOGY

In order to delineate the ophthalmic hazards associated with microwave and laser environemnts, an examination program and protocol was developed initially at the U.S. Army Electronics Command facilities at Fort Monmouth, New Jersey. In view of the need to obtain a larger segment of personnel having a high probability of exposure to the spectrum of radiations under investigation, additional data was accumulated from other sites where appropriate exposure environments existed. Moreover, as a primary objective of this investigation is to accumulate as much knowledge as possible, data concerning documented cases of injury is included.

The threshold pathology for microwave injury is different from that of laser injury. Microwave radiation produces primarily a "thermal" type of cataract making its threshold appearance in the lens capsul. Laser radiation produces primarily a retinal burn, similar to other sources of intense light, making its threshold appearance in the pigment epithelium layer of the retina. For these reasons, the emphasis of clinical examination was placed on slit-lamp biomicroscopy with stereo-photographic documentation to detect lens injury induced by microwave radiation and ophthalmoscopy with fundus photographic documentation to detect chorioretinal injury induced by high intensity light radiation.

RESULTS

The signature of injury being different for the two environments requires a dichotomy for the presentation of the results separately into microwave and laser data.

MICROWAVE DATA

Prior to this report, five instances of microwave cataracts have appeared in the literature. Analysis of these cases revealed that the initial site of pathology was not in the lens substance itself, but, instead, in the capsul surrounding the lens at its posterior surface. Ordinarily there occurred a latent period of months to years before the initial pathology appeared. Normally, the lens capsul is transparent approximately one micron thick and smooth. Careful slit-lamp examination discloses that the microwave injured capsul becomes opaque, thickened and rough. Gradually, this process spreads until the entire posterior capsul and part of the anterior capsul is involved. At this point, which again may take months to years before it appears, the individual may not yet be aware that there is anything abnormal about his eyes because the filtering effect of opacification of the thin lens capsul is minimal and the lens substance, itself, is completely transparent and refracts light normally. Although the process usually takes years to reach this stage of development, the next phase, extensive opacification of the lens substance, occurs rapidly and results in the formation of a clinical cataract associated with a loss of visual acuity. If seen for the first time at this stage, it is impossible for the ophthalmologist to determine the etiology of the cataract except by presumptive history of exposure.

In addition to the above mentioned five individuals, 26 not previously reported cases of microwave lens damage are included in this survey so that the number of documented microwave injuries now totals 31. Of the 26 new cases, only one has progressed to the stage of clinical cataract and loss of vision. Eight others have been examined more than once each and demonstrated progression of findings. The findings in the remaining 17 have either been dormant or there has only been a single examination performed.

It is premature to present any reliable statistical data concerning the incidence of microwave damage to the lens. However, at one site, there is both a high probability of exposure to levels of irradiation exceeding 10 mw/cm^2 and a good capability for obtaining reliable free-field measurements demonstrating that the permissable level was, in fact, exceeded. The most recent survey at this installation resulted in the examination of 79 men so exposed and in the discovery that 15 of them had ophthalmological evidence of microwave injury.

LASER DATA

Last year, after having examined about 60 individuals working in laser environments and analysing the results, it was found that approximately 25% had retinal pigmentary aberrations suggestive of photic injury. In none of these cases was the visual acuity reduced nor was there any known direct exposure to a laser beam. As all of these scientists have worked with other intense light sources before and during their laser employment and as exposure to any high intensity light source could produce irreversible changes in the photostabile pigments of the retina, it became obvious that the optical pumping devices, such as xenon flash lamps, were not only dangerous but also probably constituted the greatest portion of the environmental hazard associated with the laboratory use of laser devices.

For the specific types of ocular pathology found, hyperpigmentation of the macula and minute areas of depigmentation or bleaching of the retinal pigment epithelium, intense light was the etiological factor. It did not matter whether or not the source was broadly spectral in distribution or monochromatic. Although other late abiotic effects should be looked for and sporadically may, at some future time, become apparent, attention must be centered on changes in the pigment epithelium of the retina at this time for two compelling reasons.

The first is that under direct examination of the retina when it is irradiated with laser illumination, the minimal, non-transient, permanent lesion discernable is an area of depigmentation in the pigment epithelium of the retina corresponding precisely to the focal image of the laser on the retina. The second is that in two cases of inadvertant exposure of the retina to laser irradiation at approximately threshold intensities, both subjects permanently retained depigmented areas in the pigment epithelium of the retina coinciding in location and size with the retinal image of the laser beam.

To recapitulate two significant findings have been discovered in personnel inhabiting environments of high intensity light, (1) hyperpigmentation of the entire macula and (2) depigmentation of minute areas within the macula. In a pooled sample of 737 individuals working with intense light sources, approximately 25% had hyperpigmentation of the macula and 10% (70 individuals) had minute areas of permanent depigmentation in the macula. None has yet exhibited a loss of visual acuity attributable to these findings.

Aside from the above, an additional disquieting finding bears mention. In one eye of one individual a melanoma was discovered.

DISCUSSION

Microwave cataract has been found to be more prevalent than heretofore suspected. Although many of its features have not yet been fully delineated, a number of new factors have evolved and the pathogenesis has become firmly established. Ordinarily retrospective evaluations of environmental levels of irradiation cannot be performed; fortuitously, however, at one facility the capability for taking field measurements was excellent. In fact, some members of the field measurement team developed minimal but definite findings attributable to microwave radiation. The new cases discovered at this facility indicate that the threshold value for human microwave cataractogenesis may approximate 100 mw/cm^2 instead of the previously accepted, state-of-the-art value lying between 350 and 500 mw/cm^2.

Currently, photographs of the lens taken by means of the Donaldson stereo camera are the best method for documenting this type of pathology. However, the system is not sensitive enough to permit photographing the inception stage of the injury although later stages can be photographed. We are attempting to improve the camera performance by utilizing better definition film and modifying the illumination system.

Retinal changes due to intense light sources have long been known to occur. However, it has never before been suspected that hyperpigmentation of the macula was associated with such environments. A statistical incidence of this finding in 25% of potentially exposed personnel requires its complete evaluation as part of the continuing study in order to determine whether or not hyperpigmentation of the macula represents a physiological response or an early stage of irreversible injury.

Depigmentation of a minute portion of the pigment epithelium of the macula represents an irreversible injury. On the one hand, it is very surprising to find an incidence of 10%. On the other hand, it is not surprising to find that this has occurred without loss of visual acuity because each of these lesions involves a minor portion of the macula and foveal sparing has been present in all of the cases discovered to date. However, with continued exposures the probability exists that loss of vision will be sustained by a segment of this population.

The one case of melanoma, by itself, does not permit analysis. In view of the facts that it is unlikely to be found occurring spontaneously in such a small population as reported herein, that it is a type of abnormality suggestive of an abiotic effect, and that such a finding has been produced in one primate eye following exposure to laser radiation, its implication cannot be ignored. Instead, continued observation of its course and search for additional cases are required.

Documentation of the retinal findings is readily achieved by fundus photography. However, in order to permit more accurate analysis, both qualitatively and quantitatively, in the degree of hyperpigmentation, we are developing a method for obtaining densitometric measurements of this factor directly from the retinal photographs.

CONCLUSIONS

The eye serves as a unique organ in which to determine the hazards associated with the radiation environments of interest to this investigation for the following reasons:

1. Ocular tissues are injured by each of these radiation environments in a predictable manner,
2. Each form of radiation leaves its signature in a different ocular tissue,
3. Evidence of such tissue injury can be detected,
4. The susceptible ocular tissue serves as a cumulative dosimeter,
5. The ocular tissues can be examined in vivo,
6. Physiological fluctuations and sampling techniques do not alter the findings, and
7. The findings can be documented.

The findings reported to date are significant and indicate the need for continuance of this survey. In addition, they should be of value for the orientation of applied research programs designed to explore the basic mechanisms of the interaction of electromagnetic energy with biological systems.

Respectfully submitted,

Milton M. Zaret, M.D.